A 2D demo of adjoint methods for 3D remote sensing

William G. K. Martin[*] and Otto P. Hasekamp

Netherlands Institute for Space Research, Sorbonnelaan 2, Utrecht 3584 CA, Netherlands

[*]*Presenting author (willful.liam@gmail.com)*

We are developing multi-dimensional retrievals to improve the performance of remote sensing technologies near horizontal cloud edges. In earlier work, we derived the adjoint method as a computationally efficient path to three-dimensional (3D) retrievals [1]. In this talk we will show a proof-of-concept of the adjoint method using new two-dimensional (2D) radiative transfer calculation [2]. We call this simplified 2D radiative transfer code the Fourier Series Discrete Ordinate Method (FSDOM).

Using FSDOM, we generated multi-directional measurements for several synthetic cloud fields and then retrieved the cloud optical density as a 2D function of the horizontal and vertical coordinates. The retrieval algorithm minimizes the measurement misfit function with a gradient-based, quasi-Newton approach. The use of a gradient-based retrieval algorithm is important because adjoint methods allow us to compute the gradient of the misfit function with only two calls to FSDOM, regardless of the number of measurements and unknowns.

Our synthetic retrievals verify that adjoint methods are scalable to retrieval problems with many measurements and unknowns. In all cases, the vertically-integrated optical depth is recovered as a function of the horizontal coordinate. In cases where the clouds are separated by clear regions, it is possible to also retrieve the vertical profile of the cloud near its edge. In some sense, it is the horizontal heterogeneity of the cloud that enables us to retrieve its vertical profile. So, using 2D radiative transfer (relative to 1D radiative transfer) actually increases the amount of information that is available for retrieving the vertical profile.

These synthetic retrievals show that adjoint methods can efficiently compute the gradient of the misfit function, and encourage our ongoing efforts to develop 3D radiative transfer codes with adjoint derivative calculations.

References

[1] Martin, W., Cairns, B., and Bal, G., 2014: Adjoint methods for adjusting three-dimensional atmosphere and surface properties to fit multi-angle/multi-pixel polarimetric measurements. *J Quant Spectrosc. Radiat. Transfer* **144**, 68–85.

[2] Martin, W. G. K., and Hasekamp, O. P., 2018: A demonstration of adjoint methods for multi-dimensional remote sensing of the atmosphere and surface. *J Quant Spectrosc. Radiat. Transfer* **204**, 215–231.

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